FREE-AIR WINDS OVER HONOLULU AND GUAM

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Upper-air observations have been taken by the Naval Air Service at Pearl Harbor, Oahu, Hawaii, since April, 1921. The Pearl Harbor Air Station is in latitude N. 21° 22′, and longitude W. 157° 58′. Not until 1923 was any attempt made to obtain data above 2,100 meters. Since then a few high altitudes have been reached. Owing to interferences by clouds, the bursting of balloons and other causes, free-air pilot-balloon observations are fragmentary, and therefore averages obtained from such records are not wholly satisfactory.

Through the courtesy of the commandant of the Pearl Harbor Naval Station, the records obtained at the air station have been furnished to the Weather Bureau.

HONOLULU: ANNUAL AND SEASONAL FREQUENCIES OF THE VARIOUS WIND DIRECTIONS ALOFT

The result of ascents for the years 1922, 1923, and 1924 are shown in Table 1.

TABLE 1.—*Percentage of wind from different directions at different altitudes above Pearl Harbor, 1922, 1923, and 1924*

ANNUAL

Direction	Surface	250 meters	500 meters	750 meters	1,000 meters	1,500 meters	2,000 meters	2,500 meters	3,000 meters	4,000 meters	5,000 meters	6,000 meters	7,000 meters	8,000 meters	9,000 meters	10,000 meters
Number of observations	1,484	1,453	1,458	1,413	1,302	1,099	787	250	209	55	40	28	5	5	4	4
NNE. to ESE	70.5	83.2	86.6	86.7	83.0	74.2	66.5	58.0	54.7	41.6	44.4	33.3				
SSW. to WNW	5.1	3.2	3.9	4.1	6.1	10.5	12.1	20.0	21.9	27.1	27.9	48.1	100.0	100.0	100.0	100.0
Calm	4.0	2.0	0.5	0.2	0.1											
N	10.0	3.8	1.9	1.3	2.7	3.3	3.8	4.8	5.2	8.3	11.1	11.1				
NNE	15.7	4.9	2.5	2.7	3.3	3.6	5.1	4.4	8.1	8.3	11.1	3.7				
NE	15.0	19.6	16.2	13.2	9.4	9.1	9.9	11.2	10.0	10.4	8.3					
ENE	30.2	41.7	46.1	42.7	35.5	22.2	16.1	15.6	14.3	12.5	11.1	18.5				
E	8.5	15.4	19.1	24.6	30.9	31.6	26.8	18.8	13.3	4.2	11.1	3.7				
ESE	1.1	1.6	2.7	3.5	3.9	7.7	8.6	8.0	9.0	6.2	2.8	7.4				
SE	1.0	1.7	1.6	2.3	2.3	3.1	6.1	4.0	1.4	2.1	5.6					
SSE	1.0	1.3	1.7	1.4	1.8	2.3	3.9	2.8	3.8	4.2	2.8					
S	1.9	1.9	2.2	2.0	2.0	2.8	3.8	2.8	4.3	2.1	2.8	3.7				
SSW	0.9	1.2	1.6	1.3	1.4	2.0	2.2	3.6	2.4	2.1		11.1	25.0			
SW	0.7	1.1	1.1	1.5	1.8	3.0	3.4	4.8	5.2	4.2	5.6	3.7	25.0	50.0	66.7	33.3
WSW	0.5	0.2	0.5	0.6	0.8	1.4	1.9	2.8	4.8		2.8	7.4	25.0	50.0		33.3
W	1.6	0.4	0.6	0.5	1.4	2.7	2.7	4.4	6.2	14.6	13.9	18.5	25.0		33.3	33.3
WNW	1.4	0.3	0.1	0.2	0.7	1.4	1.9	4.4	3.3	6.2	5.6	7.4				
NW	2.8	0.8	0.7	0.9	0.8	2.5	2.7	3.2	3.8	2.1	2.8					
NNW	3.7	1.9	0.9	1.1	1.1	1.3	1.0	4.4	4.8	12.5	2.8	3.7				

WINTER

Number of observations	295	278	284	281	259	207	155	43	33	9	4	2	1	1	1	1
NNE. to ESE	56.4	74.1	78.2	75.8	70.3	60.4	51.6	30.2	33.4							
SSW to WNW	12.8	5.4	5.7	7.8	12.4	17.4	20.0	35.0	45.4							
Calm	4.4	1.1	0.7	0.4	0.4											
N	13.6	7.6	3.5	2.5	2.7	5.3	3.9	4.7								
NNE	13.6	8.3	3.9	5.0	5.4	5.3	5.2	2.3	6.1							
NE	13.6	18.7	19.4	16.7	11.2	9.2	8.4	11.6	3.0	11.1						
ENE	20.7	25.9	31.0	31.0	26.3	15.5	9.0	9.3	6.1		25.0					
E	7.1	19.8	19.0	17.4	20.5	19.3	16.1	4.7	12.1							
ESE	1.4	1.4	4.9	5.7	6.9	11.1	12.9	2.3	6.1	11.1		50.0				
SE	0.7	2.9	2.5	4.6	5.0	6.3	7.7	2.3			25.0					
SSE	1.7	2.2	3.2	2.8	3.5	3.4	7.7	7.0	3.0							
S	1.7	1.4	3.5	1.8	2.3	2.9	3.9		6.1							
SSW	1.7	2.2	1.8	3.2	3.5	1.9	6.5	9.3	3.0							
SW	1.0	1.4	2.1	2.1	3.9	8.2	7.1	4.7	12.1							
WSW	2.0		0.4	1.4		3.4	1.9	4.7	9.1					100.0		
W	6.4	1.1	1.4	1.1	4.2	2.9	1.3	7.0	9.1	22.2	25.0	50.0	100.0		100.0	100.0
WNW	1.7	0.7			0.8	1.0	3.2	9.3	12.1	11.1						
NW	4.7	1.1	1.4	1.4	1.5	3.4	4.5	9.3	9.6	11.1						
NNW	4.1	4.3	1.4	2.8	1.9	1.0	0.6	11.6	3.0	33.3	25.0					

SPRING

Number of observations	327	328	330	310	293	247	126	69	60	9	4	2	1	1	1	1
NNE. to ESE	72.4	78.7	79.9	80.0	73.4	61.5	55.5	47.8	45.0	22.2						
SSW. to WNW	3.6	5.1	7.5	7.5	8.8	18.5	23.8	34.7	33.0	33.3						
Calm	5.2	3.0	0.9	0.3												
N	8.6	2.7	3.0	1.3	5.8	2.0	2.4	2.9	6.7							
NNE	7.0	4.0	3.0	4.2	4.1	2.4	4.0	2.9	8.3							
NE	12.8	16.5	14.5	12.3	8.5	7.7	11.9	10.1	6.7	11.1						
ENE	37.6	38.1	39.1	34.5	27.3	16.6	10.3	14.5	13.3	0	25.0					
E	13.8	17.7	21.2	25.5	28.7	26.7	20.6	17.4	10.0							
ESE	1.2	2.4	2.1	3.5	4.8	8.1	8.7	2.9	6.7	11.1	0	50.0				
SE	1.5	2.1	2.1	4.2	2.4	3.2	5.6	5.8	0	0	25.0					
SSE	0.9	2.4	2.1	1.3	3.1	3.2	3.2	1.4	3.3							
S	2.8	3.0	2.7	3.2	3.8	5.7	6.3	1.4	5.0							
SSW	1.5	2.7	3.6	2.3	2.0	3.6	3.2	4.3	1.7							
SW	1.2	1.5	1.5	2.6	2.0	3.6	7.1	14.5	10.0							
WSW	0	0.6	1.5	1.0	1.7	2.4	3.2	5.8	8.3					100.0		
W	0.3	0.3	0.6	1.3	1.4	6.5	7.9	7.2	8.3	22.2	25.0	50.0	100.0		100.0	100.0
WNW	0.6	0	0.3	0.3	1.7	2.4	2.4	2.9	5.0	11.1						
NW	1.2	0.3	0.3	1.6	1.0	4.1	2.4	2.9	1.7	11.1						
NNW	3.7	2.4	1.2	0.6	1.7	1.6	0.8	2.9	5.0	33.3	25.0					

TABLE 1.—*Percentage of wind from different directions at different altitudes above Pearl Harbor, 1922, 1923, and 1924*—Continued

SUMMER

Direction	Surface	250 meters	500 meters	750 meters	1,000 meters	1,500 meters	2,000 meters	2,500 meters	3,000 meters	4,000 meters	5,000 meters	6,000 meters	7,000 meters	8,000 meters	9,000 meters	10,000 meters
Number of observations	459	457	454	439	405	330	256	91	77	29	26	21	3	3	2	2
NNE. to ESE.	83.9	94.1	96.2	97.0	96.6	92.1	80.1	82.5	75.4	55.1	46.1	28.7				
SSW. to WNW	1.1	0.4	0.4	0	0.2	1.2	4.0	4.4	6.5	17.1	23.0	52.9	99.9	100	100	100
Calm	2.2	1.8	0.2													
N	8.1	0.7	0.2		0.2	1.8	4.3	4.4	5.2	13.8	11.5	9.5				
NNE	18.3	2.2	0.4	0.2	0.5	2.1	5.9	7.7	11.7	13.8	11.5	4.8				
NE	17.0	19.7	14.5	10.9	8.4	9.4	9.4	14.3	14.3	13.8	7.7					
ENE	36.8	51.2	58.6	55.6	45.7	33.3	23.8	22.0	18.2	17.2	7.7	14.3				
E	10.5	19.9	20.5	28.7	39.5	40.6	33.6	28.6	16.9	6.9	15.4	4.8				
ESE	1.3	1.1	2.2	1.6	2.5	6.7	7.4	9.9	14.3	3.4	3.8	4.8				
SE	0.2	0.4	1.3	0.7	1.2	1.5	6.6	1.1	2.6	3.4	3.8					
SSE		0.4	0.4	0.9	0.5	0.6	2.0	2.2		6.9	3.8					
S	1.1	0.9	0.7	1.1	0.7	1.5	0.8	3.3	3.9			4.8				
SSW			0.4		0.2	0.9	0.8	1.1	1.3	3.4		14.3	33.3			
SW		0.2				0.3	1.6		1.3		7.7	4.8	33.3	66.7	100	50.0
WSW							0.8		1.3		3.8	9.5	33.3	33.3		
W	0.2	0.2					0.4	2.2	2.6	10.3	11.5	14.8				50.0
WNW	0.9						0.4	1.1		3.4		9.5				
NW	1.7	0.9	0.2		0.2	0.9	2.0	2.2	1.3		11.5					
NNW	1.7	0.4	0.2	0.2	0.2	0.3	0.4	1.1	5.2	3.4		4.8				

AUTUMN

Number of observations	403	390	390	383	345	315	250	47	39	8	6	3				
NNE. to ESE.	65.5	82.2	86.3	87.7	82.0	74.9	67.6	53.1	46.2	25.0	50.1	66.7				
SSW. to WNW	5.1	3.1	3.4	3.7	7.6	9.1	9.6	14.8	15.4	37.5	16.7					
Calm	5.0	1.3	0.5	0.3												
N	10.9	5.1	1.8	2.1	3.4	4.4	4.0	8.5	7.7		16.7	33.3				
NNE	21.6	4.6	3.3	2.6	2.6	5.1	4.8	2.1	2.6		16.7					
NE	15.9	21.0	17.2	14.1	9.6	9.8	10.4	6.4	12.8		16.7					
ENE	24.1	45.4	47.9	44.1	35.1	19.4	15.6	10.6	15.4	12.5	16.7	66.7				
E	3.2	9.7	15.6	24.8	31.3	34.3	29.6	17.0	10.3							
ESE	0.7	1.5	2.3	2.1	3.4	6.3	7.2	17.0	5.1	12.5						
SE	1.7	2.1	1.0	0.8	1.4	2.5	4.8	8.5	2.6							
SSE	1.7	0.8	1.8	1.0	1.7	2.5	4.0	2.1	12.8							
S	2.2	2.8	2.6	2.1	1.4	1.9	5.6	6.4	2.6	12.5	16.7					
SSW	0.7	0.5	1.0	0.8	0.9	1.9	0.4	2.1	5.1							
SW	1.0	1.5	1.3	2.1	2.9	1.9	1.2			25.0						
WSW	0.2	0.3	0.3	0.5	1.4	0.6	2.4	2.1	2.6							
W	0.7	0.3	0.8		1.2	2.5	3.2	2.1	7.7		16.7					
WNW	2.5	0.5		0.3	1.2	2.2	2.4	8.5		12.5						
NW	2.2	0.5	1.0	1.0	1.2	2.2	2.4		7.7							
NNW	5.4	2.1	1.5	1.3	1.2	2.2	2.0	6.4	5.1	25.0						

At the surface, 80 per cent of the winds are from N. to E., with ENE. winds 30 per cent of the time. Winds from all the other points have occurred, but none more than 4 per cent of the time.

The most prevalent winds at the 1,000-meter level are between NE. and E., with ENE. winds dominating. The percentage between NE. and E. is 76, and the percentage of ENE. winds is 36. Winds from all the other directions have occurred, but the percentage of any single direction was not greater than 3. The main feature in ascending from the surface to an elevation of 1,000 meters is the decrease in the number of N., NNE., and NE. winds, and the increase in ENE. and E. winds, especially the E. winds, which have gained 22 per cent in frequency at the 1,000-meter level.

At an altitude of 2,000 meters the percentage of the directions between NE. and E. is still dominant, but only amounts to 53 as against 76 at the 1,000-meter level. At the 2,000-meter level, E. winds are the most frequent and their percentage is 27. At this level there has been a gain from the 1,000-meter level amounting to 5 per cent in ESE. winds and 4 per cent in SE. winds. All the other directions have increased their frequency slightly, except those from NNW. which have the same percentage as before. From the foregoing it can be seen that the winds at the 2,000-meter level are more variable in direction than they are anywhere else below that level.

The figures for the 3,000-meter level show the percentages between NE. and E. to be 38, with ENE. winds in the ascendency and their percentage 14, which is only one point above winds from the east. The prevailing winds between NE. and E. have decreased in frequency from 53 to 38 in going from the 2,000-meter to the 3,000-meter level. SE. winds now show a falling off in frequency of 5 per cent, and the principal gains have been made by winds from a westerly quadrant, with their north and south components about equally divided. The variability in direction at the 3,000-meter level is slightly greater than it is in the levels below.

Directions in arcs of 90°.—There are too many factors involved to make practicable a further analysis for each of the 16 compass points, so the data have been assembled into four primary directions as follows: Winds from anywhere between NNE. and E. are considered northeasterly; those between ESE. and S. as southeasterly; those between SSW. and W. as southwesterly; and those between WNW. and N. as northwesterly. This puts in one class all the NE. trade winds, which are the most frequent, and the other groups fit naturally into this arrangement.

In this system of groups their ratios, assuming the group of greatest frequency of winds to be 10, are as follows: NE. 10, SE. 2, SW. 1, and NW. 1.

All the percentages from the surface to the 3,000-meter level are included to obtain these ratios and they show clearly the dominating influence of the northeasterly group over all the others from the surface to 3,000 meters.

Seasonal ratios of the most frequent wind directions aloft.—Assuming that 5 represents the greatest frequency

in wind direction for any one season, the ratios for the different groups for each season are given in Table 2.

TABLE 2.—*Ratio of wind directions for different seasons surface to 3,000 meters*

Quadrants	Spring	Summer	Autumn	Winter
NE	4	5	4	3
SE	4	3	4	5
SW	5	1	2	5
NW	3	2	4	5

Table 2 shows that NE. winds are most frequent in summer, and winds from all other directions most frequent in winter, except SW. winds, which are nearly as frequent in spring as in winter. NE. winds are least frequent in winter and those from other groups least frequent in summer. From this table aviators can ascertain at a glance the seasons when winds from the different quadrants are most likely to occur. For example, SW. and NW. winds are rare in summer, but they do occur quite frequently in winter, and SW. winds are almost equally as frequent in the spring, but NW. winds are more frequent in autumn than in spring.

Altitudes of maximum and minimum frequencies, for four wind directions, by seasons.—Next are presented Tables 3 and 4, showing the altitude of the greatest and the least frequencies of wind in the four groups by seasons, as obtained from all data available between the surface and 3,000 meters.

Tables 3 and 4 show that when their frequency is greatest the NE. winds have a low altitude and those from the other directions a high altitude. It would seem, therefore, that the observations covered fairly well the NE. trade winds, which are most frequent in spring and winter at an elevation of 500 meters and in summer and autumn at 750 meters. They are much less frequent at all seasons at an altitude of 3,000 meters, and probably disappear somewhere between an altitude of 5,000 and 6,000 meters, though during the summer months they may be experienced at higher levels.

TABLE 3.—*Altitude of greatest frequency of winds during each season from surface to 3,000 meters above Pearl Harbor*

Quadrants	Altitude (meters)			
	Spring	Summer	Autumn	Winter
NE	500	750	750	500
SE	2,000	3,000	2,500	2,000
SW	2,500	3,000	3,000	3,000
NW	3,000	3,000	2,500	2,500

TABLE 4.—*Altitude of least frequency of winds during each season from surface to 3,000 meters above Pearl Harbor*

Quadrants	Altitude (meters)			
	Spring	Summer	Autumn	Winter
NE	3,000	3,000	3,000	3,000
SE	Surface.	Surface.	Surface.	Surface.
SW	Surface.	Surface.	Surface.	250
NW	750	750	500	500

Winds from other than a northeasterly direction gain in frequency with altitude, but it is not definitely known at just what levels they reach their maximum frequency. In autumn and winter the records show that westerly winds are not quite so frequent at 3,000 meters as they are at 2,500 meters. This is probably an error due to the scarcity of observations above 2,500 meters. It should be borne in mind, also, that during cloudy weather observations can not be made, and those we have were taken when clouds were insufficient to prevent the balloon from being followed to the conclusion of the run. At Pearl Harbor more cloudiness occurs with westerly than with northeasterly winds.

Turning of trade winds with altitude.—The trade winds here generally turn to the right up to about 2,500 meters, when a reversal in the turning takes place, and they shift back to their former position. This phenomenon is also found in the United States, as noted by Gregg (3): "Near the surface the turning of the winds is generally to the right, no matter what the surface directions may be. * * * With west-northwest winds, through north to northeast or east-northeast, the turning is to the right, but small in amount up to about 1 kilometer, and then changes to the left at higher levels."

The Pearl Harbor record shows that the trade winds continue a slow turning to the right up to about 2,500 meters before they change to the left. The turning probably is due to the persistency of the trade winds and to the enormous field they cover, which is much greater than the United States, where Gregg's information was obtained.

The loss in the frequency of the NE. trade winds above altitudes of 500 and 750 meters is largely compensated by a gain in the frequency of winds from a westerly quadrant. The gain is made by winds having both a northerly and a southerly component of nearly equal proportions.

Neither temperature nor humidity data has ever been obtained in the upper atmosphere within the region of the North Pacific trade winds, so far as known by the writer; therefore the causes that produce pressure gradients that in turn result in this loss of northeasterly and the gain of westerly winds at relatively low altitudes await further investigation before they can be definitely ascertained.

GUAM: FREE-AIR WIND DIRECTIONS

The report received from Guam (latitude 13° 30′ N., longitude 144° 56′ E.) of upper-air observations in the Pacific Ocean is not so complete as the one from Pearl Harbor. The observations were taken by aerologists attached to the United States Marine Corps. The mean monthly resultant wind directions for the period 1921–1924 are presented in Table 5.

The total number of observations is only 568 at the surface. They become gradually less up to the 1,000-meter level, after which they diminish rapidly to 234 observations at 2,000 m. to 95 at 3,000 m. to 47 at 4,000 m. and to one observation at 10,000 m. The fewness of the observations makes the means somewhat uncertain, though the steadiness of atmospheric conditions so near the Equator, and so far from disturbing influences of large land masses, may offset this drawback to some extent.

The data can not be segregated into percentages for individual directions, as only the prevailing winds are given, and not the number of times each direction was observed.

About all that can be said regarding these data is that from the surface up as far as the observations were made the prevailing winds are ENE. for more than half of the time. There were no months with prevailing winds from a westerly quadrant, except one W. at 8 km., one

NW. at 7 km. and one NNW. at 5 km. Two of these occurred in September and one in October. It is quite apparent from these observations, that the antitrades, if there are any at such a low latitude, occur in this portion of the ocean only near the upper boundary of the troposphere.

TABLE 5.—*Mean monthly resultant wind directions at Guam, 1921–1924*

No. obs.	Alt. km.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
568	Sur.	ene.	e.	ene.	e.	e.	e.	ese.	ese.	e.	e.	ene.	e.	e.
568	0.25	ne.	ene.	ene.	ene.	e.	ene.	e.	se.	ene.	e.	ene.	ene.	ene.
567	0.50	ne.	ene.	ene.	ene.	e.	ene.	e.	ese.	e.	ene.	ene.	ene.	ene.
562	0.75	ne.	ene.	ene.	ene.	e.	ene.	o.	ese.	ene.	ene.	ene.	ene.	ene.
540	1	ene.	ene.	ene.	ene.	e.	ene.	e.	ese.	ene.	ene.	ene.	ene.	ene.
381	1.5	ene.	ne.	ene.	ene.	e.	ene.	e.	ese.	ene.	ene.	ene.	ene.	ene.
234	2	ene.	ene.	ene.	ene.	ene.	ene.	e.	e.	ene.	ene.	ene.	ene.	ene.
137	2.5	ne.	ene.	e.	ene.	ene.	e.	ene.	e.	ene.	ene.	ene.	ene.	ene.
95	3	ene.	ene.	ese.	e.	ene.	ene.	ne.	e.	e.	ene.	ene.	ene.	ene.
47	4	ene.	e.	se.	-----	-----	-----	ene.	e.	e.	e.	ene.	ene.	ene.
20	5	e.	ese.	-----	-----	-----	-----	-----	se.	e.	nnw.	ne.	ene.	e.
16	6	e.	ese.	-----	-----	-----	-----	-----	ne.	ene.	ene.	ne.	se.	e.
5	7	-----	ese.	-----	-----	-----	-----	-----	-----	nw.	ne.	ne.	ese.	ene.
3	8	-----	ese.	-----	-----	-----	-----	-----	-----	w.	-----	-----	e.	ese.
2	9	-----	ese.	-----	-----	-----	-----	-----	-----	-----	-----	-----	e.	ese.
1	10	-----	ese.	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	ese.

August is the only month with ESE. and SE. winds between the 250 m. and the 2,000 m. levels. Between the 250 m. and the 1,500 m. levels the winds during May and July are E. while in the intervening month they are ENE. at the same levels. This is a singular phenomenon not easily explained.

Table 5 gives no evidence of a turning of the wind with increase of altitude, although the ESE. and SE. winds outnumber slightly those from NE. and ENE. from the 5,000 m. level up to the limit of observations.

COMPARISON OF UPPER-AIR VELOCITIES AT PEARL HARBOR AND GUAM

These are presented in Table 6. The number of upper-air observations are those already given for these stations.

TABLE 6.—*Average wind velocity (m. p. s.), according to pilot balloon observations taken at Pearl Harbor and Guam*

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Seasons	Surface	250	500	750	1,000	1,500	2,000	2,500	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000
Winter	4.3	4.9	6.0	6.6	6.6	6.4	5.6	6.0	6.8							
Spring	4.5	4.9	5.4	5.8	5.7	5.2	5.2	5.0	5.2	7.0	5.2	4.0	(A few scattered observations. See Table 1.)			
Summer	5.2	5.3	6.0	6.8	7.1	6.5	5.7	5.8	5.7	5.8	5.9	6.9				
Autumn	4.5	5.4	6.0	6.8	6.6	5.9	6.0	5.2	3.8	2.6	4.2	5.2				
Annual (m. p. s.)	4.7	5.1	5.8	6.5	6.5	6.0	5.6	5.5	5.4	5.5	5.5	6.4	8.2	10.8	13.3	16.3
Annual (approx. m. p. h.)	10	11	13	14	14	13	12	12	12	12	12	14	18	24	30	36

GUAM

Winter	3.0	8.3	10.2	10.8	10.0	9.1	7.5	7.1	5.6	6.0						
Spring	2.8	7.6	9.1	9.9	10.1	8.5	6.6	6.9	6.5	4.0	(A few scattered observations. See Table 5.)					
Summer	2.6	5.4	6.2	6.7	6.8	6.3	7.1	5.4	4.6	6.5						
Autumn	2.6	6.0	7.0	7.5	7.5	7.2	6.9	6.2	6.1	4.2						
Annual (m. p. s.)	2.9	6.9	8.2	8.9	9.0	7.8	6.9	6.4	6.0	5.9	5.0	6.1	8.0	9.3	10.0	9.0
Annual (approx. m. p. h.)	6	15	18	20	20	17	15	14	13	13	11	14	18	21	22	20

Yearly average wind velocities over Pearl Harbor.—The average yearly wind velocity at Pearl Harbor is lowest, 4.7 m. p. s., at the surface. It slowly increases to 6.5 m. p. s. at 1,000 m., after which it quickly decreases to 5.6 m. p. s. It remains very nearly at this velocity up to 5 kilometers, when another increase occurs. This second increase is progressive up to 8 kilometers, being nearly 1 m. p. s. between 5 and 6 kilometers, nearly 2 m. p. s. between 6 and 7 kilometers, and 2.6 m. p. s. between 7 and 8 kilometers. During the next step up to the 9-kilometer level the increase in velocity is only 2.5 m. p. s., but in going from 9 to 10 kilometers the increase is 3 m. p. s., which gives 16.3 m. p. s. (36 miles) as the velocity at an altitude of 10 kilometers.

Yearly average wind velocities over Guam.—The average yearly wind velocity at Guam is lowest, 2.9 m. p. s., at the surface. It increases rapidly between the surface and the 250-m. level, and then slowly to the 1-km. level. Between the 1 and 5 km. levels the velocity gradually decreases. Above 5 km. the wind steadily increases up to 9 km., where it is strongest, with an average velocity of 10 m. p. s. (22 m. p. h.). At 10 km. the velocity is only 9 m. p. s. (20 m. p. h.). It is probable if more observations were available at this level, instead of a decrease there would be an increase in harmony with that at Pearl Harbor at this altitude.

The change in velocity, first an increase up to 750 or 1,000 meters, followed by a decrease to velocities which continue below those at the 1-km. level, up to an altitude of 6 kilometers before again increasing, is similar to the changes at Pearl Harbor, and probably is universal in the trade wind zone.

Seasonal average wind velocities over Pearl Harbor.—By seasons the average wind velocity at Pearl Harbor, from the surface to the 3 km. level, is strongest in summer, and weakest in spring. From the 1 km. to the 2 km. level, the velocities decrease during all seasons, with the greatest decrease in summer and the least in spring. Between the 2 and 3 km. levels the velocities are the same in spring and summer. In winter there is a slight increase, and in autumn there is a decrease of 2.2 m. p. s. The highest velocity, 7.1 m. p. s., occurs in summer at the 1 km. level, and the lowest, 2.6 m. p. s., in autumn at 4 km.

Up to 2 km. there is no great variation in wind velocity throughout the year, but at altitudes above 2 km. seasonal differences become more marked. At 3 km. the winds in winter are strongest, averaging 6.8 m. p. s., and in autumn they are weakest, averaging 3.8 m. p. s., which makes a spread between winter and autumn of 3 m. p. s. At 4 km. the record for the winter months is missing, but the spread at the other seasons between the highest and lowest is 4.4 m. p. s.; the highest velocity being 7 m. p. s. in spring and the lowest 2.6 m. p. s. in autumn. Other details can be drawn from the table.

Seasonal average wind velocities over Guam.—By seasons the average velocity of the wind at Guam from the surface to 3 km. is strongest in winter and weakest in summer. At Pearl Harbor at similar elevations the winds are strongest in summer, and the fact that they are strongest at Guam in winter is undoubtedly because Guam at that season of the year is largely under the influence of the Siberian anticyclone.

From the surface to 1 km. the summer winds show the least increase, and those of winter the greatest, with the next increase in spring. Between 1 and 2 km. there is a decrease in velocity, except in summer, when the winds are stronger at 2 km. than at the 1 km. During the other

seasons the decrease in velocity is greatest in spring. Between 2 and 3 km. the winds decrease in velocity during all seasons, most markedly in summer, and least in spring. The highest velocity, 10.8 m. p. s., occurs in winter at 750 m., and the lowest, excluding the surface winds, is 4 m. p. s. at 4 km.

General comparison.—The winds at Guam have a smaller velocity at the surface than those at Pearl Harbor but from 250 m. up to and including the 4 km. level they are stronger than at Pearl Harbor. From the 5 km. level to the 10 km. level the Pearl Harbor winds are strongest.

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NOTABLE TORNADOES OF MAY, 1927

[Condensed from reports furnished by George Reeder, H. S. Cole, and A. W. Shilling]

Tornadoes of May 8 and 9 in Missouri.[1]—Severe tornadoes occurred in Missouri on both dates. The one of the 8th was first observed in the southwest part of Camden County, moving thence in a northeasterly direction to Audrain County, a distance of 110 miles, where it disappeared.

The May 9 tornado, or as it doubtless will be known in the future, the Poplar Bluff tornado, because it literally demolished the town of that name, entailed a loss of life of 86 persons in Butler County, 83 being killed in Poplar Bluff. Three hundred were injured and the property loss in Poplar Bluff and Butler County is placed at $2,100,000. This storm was first observed in the southwestern part of Randolph County, Ark.; it moved thence to Poplar Bluff, striking that city at 3.15 p. m. In this city, of from 8,000 to 10,000 inhabitants, less than a dozen buildings remained standing, and even these were badly damaged. After leaving Poplar Bluff the force of the storm seems to have been spent, although strong east and northeast winds were observed some 60 miles to the northeast.

Mr. Reeder recites two rather unusual incidents in connection with these storms. The first was that of a well-constructed farmhouse that was bolted to a concrete foundation with half-inch iron bolts. This house was completely wrecked and two persons were killed in the basement by being crushed by great blocks of concrete torn from the foundation. The second incident was the killing of six persons who were caught in a touring car by the storm that overtook Poplar Bluff.

Arkansas.[2]—No tornadoes occurred in this State on the 8th; but an unusually large number, 11, were reported on the 9th. These storms passed through 25 different towns and communities, 71 persons lost their lives, 449 were injured, and the property loss was estimated at $1,223,000.

The geographic position of the tornadoes of the 8th and 9th are shown on regular Chart No. II at the end of this REVIEW, those of the 8th by black crosses and those of the 9th by black dots.

The tornadoes in Arkansas began a little after 2 p. m. in the northwestern part of the State and developed later and later in the day with distance to the eastward; the last storm was first observed at 4:25 p. m. Details as to these storms will be found in the general table on pages 247–250 of this REVIEW.

Nebraska.[3]—On the 8th between 6 and 6:30 a. m. (105th meridian time) a tornado with a path approximately 34 miles long passed across Lincoln County, Nebr., moving in a direction slightly west of north on a line about 5 miles west of the Weather Bureau station at North Platte. No lives were lost in this storm and the damage was confined to farm buildings. The unusual direction of movement of this storm was probably due to the fact that the cyclonic winds in which it originated were moving from the east and southeast.

DISCUSSION

May 8 and 9.—The cyclonic system within which the tornadoes above described occurred was exceptional for the season, particularly because of the low level of the pressure in the center, the track followed by the depression, and its relatively slow progressive movement. See Chart II, track No. IIa.

The pressure gradient over Arkansas and Missouri was not at any time more than fairly steep, nor was it any steeper than that over the adjoining States of Oklahoma, Kansas, and Iowa, in which tornadoes were not reported. Neither was the surface-temperature gradient steep at any time. The 7 o'clock a. m. temperatures over both Missouri and Arkansas on the morning of the 8th were around 70°. There was, however, a steep surface-temperature gradient in the rear of the cyclonic center, especially on the 8th, when the temperature in the cyclone center was 18° to 20° lower than about 200 miles eastward.

The surface wind-shift line on the morning of the 8th was at least 300 miles west of the western border of the State, where tornadoes occurred, and largely because of the northward movement of the cyclone a surface wind-shift line did not pass across either Arkansas or Missouri. The Nebraska tornado occurred in the northeast quadrant and distant about 200 miles from the cyclone center. A pronounced anticyclone was absent on both dates.

In Arkansas the time of occurrence of tornadoes was progressively later and later with distance toward the east. If we can imagine an impulse moving wavelike from west to east, its rate of progression across the State would have been about 25 miles per hour.

The fact that severe tornadoes occurred in Missouri on both dates and in Arkansas only on the 9th is rather puzzling. It might be interpreted as being due to dependence of tornadoes upon conditions of atmospheric instability of more or less local origin which exercises their full influence when, and only when, the presence of a cyclonic system brings about the opportunity of creating an energetic whirl.

The free-air conditions over Arkansas and Missouri may be inferred, approximately at least, by the records of one kite station in Oklahoma and several pilot-balloon stations in neighboring States. These are presented in the

[1] Condensed from a report by George Reeder in Climatological Data for Missouri, May, 1927.
[2] Condensed from a report by H. S. Cole.
[3] Condensed from a report by A. W. Shilling.